Report No. RD-64-157

FINAL REPORT

Project No. 320-205-02X

LIMITED SURVEY OF COMMERCIAL JET AIRCRAFT ALTIMETER SYSTEM POSITION ERROR BY PACER WITH TRAILING CONE

DECEMBER 1964

FEDERAL AVIATION AGENCY

Systems Research & Development Service

Atlantic City, New Jersey

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Prepared by:

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December 1964

This report has been approved for general availability. It does not necessarily reflect FAA policy in all respects and it does not, in itself, constitute a standard, specification or regulation.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (continued)

Federal Aviation Agency, Systems Research and Development Service, National Aviation Facilities Experimental Center, Experimentation Division, Atlantic City, N. J.
LIMITED SURVEY OF COMMERCIAL JET AIRCRAFT ALTIMETER SYSTEM POSITION ERROR BY PACER WITH TRAILING CONE by Jack J. Shrager, Final Report, December 1964, 33 pp. including 23 illus.
(Project No. 320-205-02X, Report No. RD-64-157)

ABSTRACT

Limited flight tests were conducted using the trailing cone static pressure measuring technique to determine the repeatability of commercial jet aircraft altimeter systems. The maximum difference between the six types tested at 30,000 feet was 500 feet.

INTRODUCTION

This report is concerned with limited tests conducted by SRDS to determine the apparent repeatability of the static pressure portion of a commercial jet aircraft's airspeed system.

The purpose of these tests was to establish the difference between the indicated pressure altitude and true ambient pressure altitude at nominal cruise altitude. The tests were to include 3 aircraft of 13 different operational and commercial type jets, a total of 39 airplanes.

The tests were conducted in the vicinity of the FAA's National Aviation Facility Experimental Center (NAFEC), Atlantic City, New Jersey, Aeronautical Center, Oklahoma City, Oklahoma, and Miami International Airport, Miami, Florida.

TEST PROCEDURE

The procedure employed for these tests was a tower pass and a modified pacer method.

The tower pass technique involved the test aircraft making low altitude passes over a vertically aimed aerial camera set up on the ground. The differences between indicated and computed altitude were determined as described in detail in SRDS Report No. RD-64-37. This procedure was also used to verify the sea-level calibration characteristics of the calibrated TV-2 pacer and trailing cone.

The modified pacer technique with trailing cone was as follows:

1. The pacer aircraft flew in close formation but out of the aircraft generated turbulence with the commercial jet during the low-level tower passes. At the instant of passing over the ground camera, a reading of the pilot's and copilot's airspeed and altimeter, using the primary static source was made. At this instant, upon radio command, a picture of the photopanel shown in Fig. 1 was made.

2. At the completion of the low-level phase of the tests, the large jet and the pacer climbed to the test altitude under positive air traffic control.

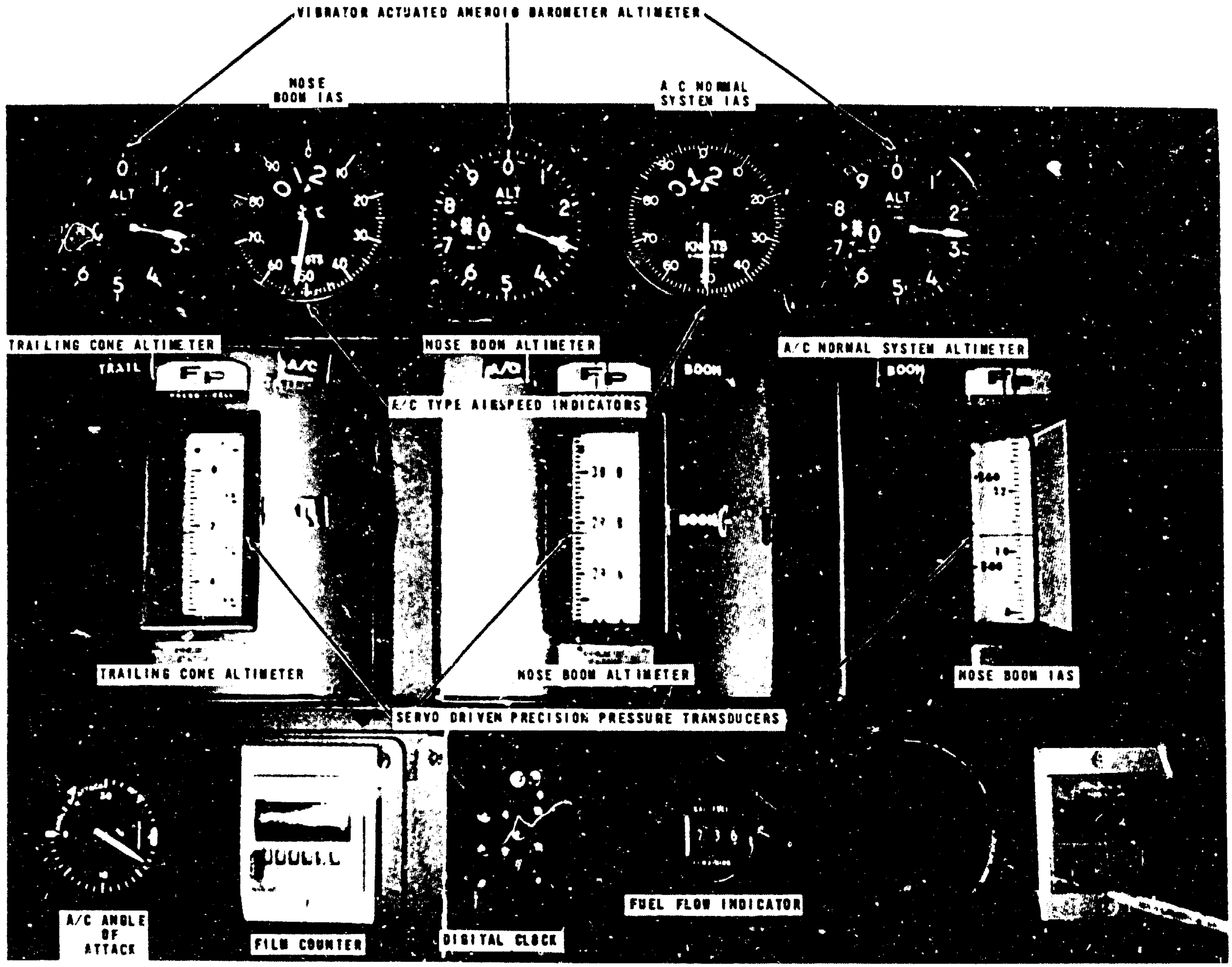

FIG. 1 PACER AIRCRAFT'S PHOTOPANEL

3. Readings of the pilot's and copilot's instruments and photographs of the TV-2 photopanel were taken at several different speeds from minimum controllable in the clean configuration of the commercial jet transport to maximum continuous speed of the TV-2 pacer.

4. To obtain data above the limiting speed of the pacer, the larger jet would reduce speed to allow sufficient horizontal distance between the pacer and the slower moving large jet for acceleration. At all times during these procedures, visual contact backed up by positive radar control was maintained. When sufficient horizontal separation was attained, the commercial jet aircraft accelerated to the first test speed which was in excess of the TV-2 capability. Upon attaining the desired test speed, the large jet steadied out in straight, level, unaccelerating flight at the apparent visual altitude of the TV-2 pacer. Upon overtaking the pacer in very close horizontal and vertical proximity, the pilot's and copilot's airspeed, altitude readings, and TV-2 photopanel were recorded.

5. This procedure was repeated for several different flight speeds up to the maximum continuous speed of the larger aircraft.

6. These runs were made in ascending and descending speed increments after which the aircraft returned to the airport for additional low-level tests and landing.

In the tests involving the FAA's Boeing 720, a trailing cone similar to that used with the TV-2 pacer was mounted in the tail cone of the Boeing 720. The length of trail was approximately 120 feet.

TEST EQUIPMENT

Pacer Aircraft

A light-weight, high-drag fiberglas cone, Fig. 2, was attached to a hollow nylon tube. Inserted in the nylon tube approximately 10 feet forward of the cone was a stainless steel tube with three sets of perpendicularly drilled static ports. A 1/32-inch piano wire was threaded through the nylon tubing to carry the drag loads of the cone and tubing assembly. The anchor point for the tubing assembly was a motor-driven reel installed internally on the underside of the fuselage of the TV-2. Through cockpit-located controls, it was possible to extend or retract the cone assembly up to distances of 40 feet behind the TV-2 while in flight.

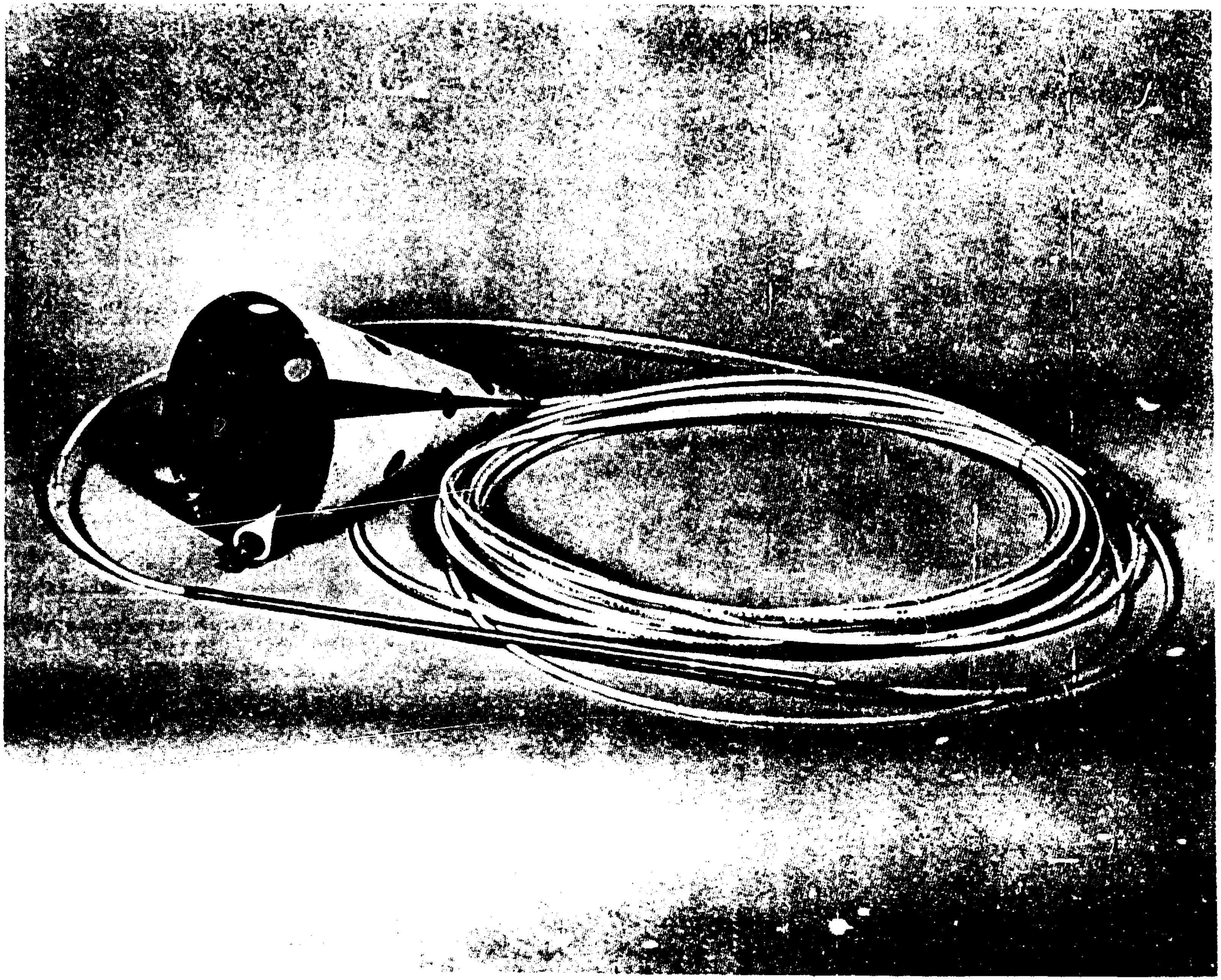

FIG. 2 FIXED GEOMETRY TRAILING CONE ASSEMBLY

The aircraft end of the tubing was led to a high-precision, servo-driven pressure transducer and a selected low-hysteresis aneroid altimeter. These instruments along with the others shown in Fig. 1 were mounted on a rack which replaced the rear seat of the TV-2. All the instruments were photographed by a high-speed motion picture camera operated by the pilot.

In the case of the trailing cone installation on the Boeing 720, the cone trailed approximately 120 feet behind the FAA's 720 and was not retractable. In this particular case, the aircraft took off and landed with the cone assembly extended.

Test Aircraft

The individual carriers selected standard aircraft altimeters and airspeed indicators which exhibited good repeatability and low hysteresis and replaced the aircraft's normal instruments with these test instruments. The airspeed system was then checked to assure pressure integrity. During all flight tests, the altimeter setting regardless of altitude was 29.92" Hg.

Ground Test Site

The equipment at the ground test site included the following:

1. Precision aerial camera Type T-11.
2. Aneroid barometer of the weather bureau type.
3. Aspirating wet and dry bulb thermometers.
4. Portable transceiver.

This equipment is described at greater length in the SRDS Report No. RD-64-37.

METHOD OF ANALYSIS

The methods employed to determine the difference between indicated pressure altitude and computed pressure altitude for the low-level tests are described in SRDS Report No. RD-64-37.

The method employed for determining this at altitude was the difference between the calibrated trailing cone static system and that indicated by the test aircraft pilot's and copilot's instruments. The performance and calibration of the trailing cone system are discussed in SRDS Report No. RD-64-156. Figures 3a and 3b indicate the nominal position error of the trail cone system as also noted in the above referenced report. The repeatability of

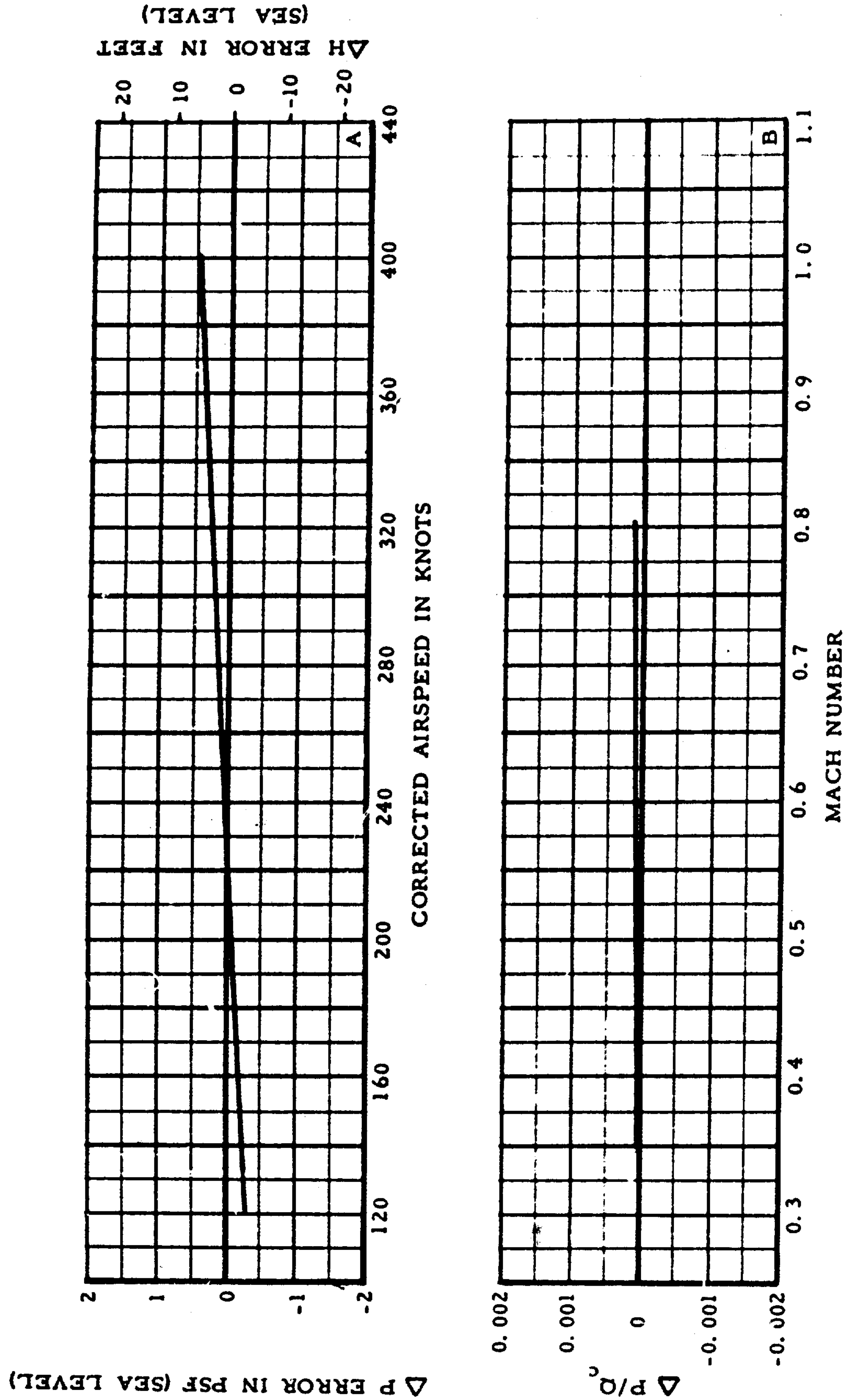

FIG. 3 SEA LEVEL CALIBRATION OF TRAILING CONE SYSTEM

the system is within that of the readout instruments and calibration method which, in the case of NAFEC, was + 0.004" Hg. (± 0.125mb) and the equivalent of ± 0.005" hg. (∓ 0.169mb), respectively. The resultant differences were statistically analyzed through a least squares and linear regression analysis to establish the best fit straight line for the actual data points.

The method of analysis noted above incorporates the following assumptions:

1. The instrument errors of the selected carrier instruments were of small enough magnitude to be disregarded.

2. The geometric difference in height between the test aircraft and pacer during the overtake portion of the tests were small enough to disregard.

3. The atmospheric conditions at altitude during the test period were constant.

The calibration of the pacer - trail cone - special instrumentation system was validated during the low-level flights which immediately preceded and followed the altitude tests.

TEST RESULTS

Figures 4 through 17 indicate the differences between the indicated altitude of the test aircraft pilot's and copilot's altimeter reading, and the calibrating pacer's trailing cone-sensed pressure altitude expressed in feet versus the pilot's uncorrected indicated air speed for each test point. The altitude at which the data was obtained is indicated in the legend of each figure in terms of thousands of feet represented by the letter "K", such as 31K = 31,000 feet. The difference between the pilot's and copilot's altimeter calibration, where known, was applied as a correction to the copilot's altimeter reading. The straight line drawn through these points is the least squared derived first degree fit of all data points shown.

In most cases, the pilot's and copilot's systems exhibited similar slopes which could differ by as much as 100 feet, as noted on Fig. 5. This difference can be due only to "position error" by the defined method of analysis.

Figures 18 through 23 indicate the differences in the slopes for each of the aircraft types tested. The maximum difference between aircraft of a given type at 30,000 feet was 450 feet, as noted in Fig. 18.

Figure 23 is a composite noting the maximum difference between all aircraft types tested incorporating both the pilot's and copilot's systems. The maximum difference between the several systems was 500 feet.

CONCLUSIONS & RECOMMENDATIONS

It is noted that only 15 of the desired 39 aircraft were tested due to the non availability of the commercial jet aircraft. Due to the limited nature of the data, therefore, no technical conclusion can be drawn and, accordingly, no recommendations based on present data can be made.

REFERENCES

1. Shrager, Jack J., "Calibration Static Pressure Systems at Low Altitudes", March 1964, Project No. 115-22N, Report No. RD-64-37 Experimentation Division, Systems Research and Development Service, Federal Aviation Agency, Atlantic City, New Jersey

2. Shrager, Jack J., "Test of Trail Cone System to Calibrate Static Ports for Barometric Altimeters", Project 320-205-02X, Report No. RD-64-156, Experimentation Division, Systems Research and Development Service, Federal Aviation Agency, Atlantic City, N. J.

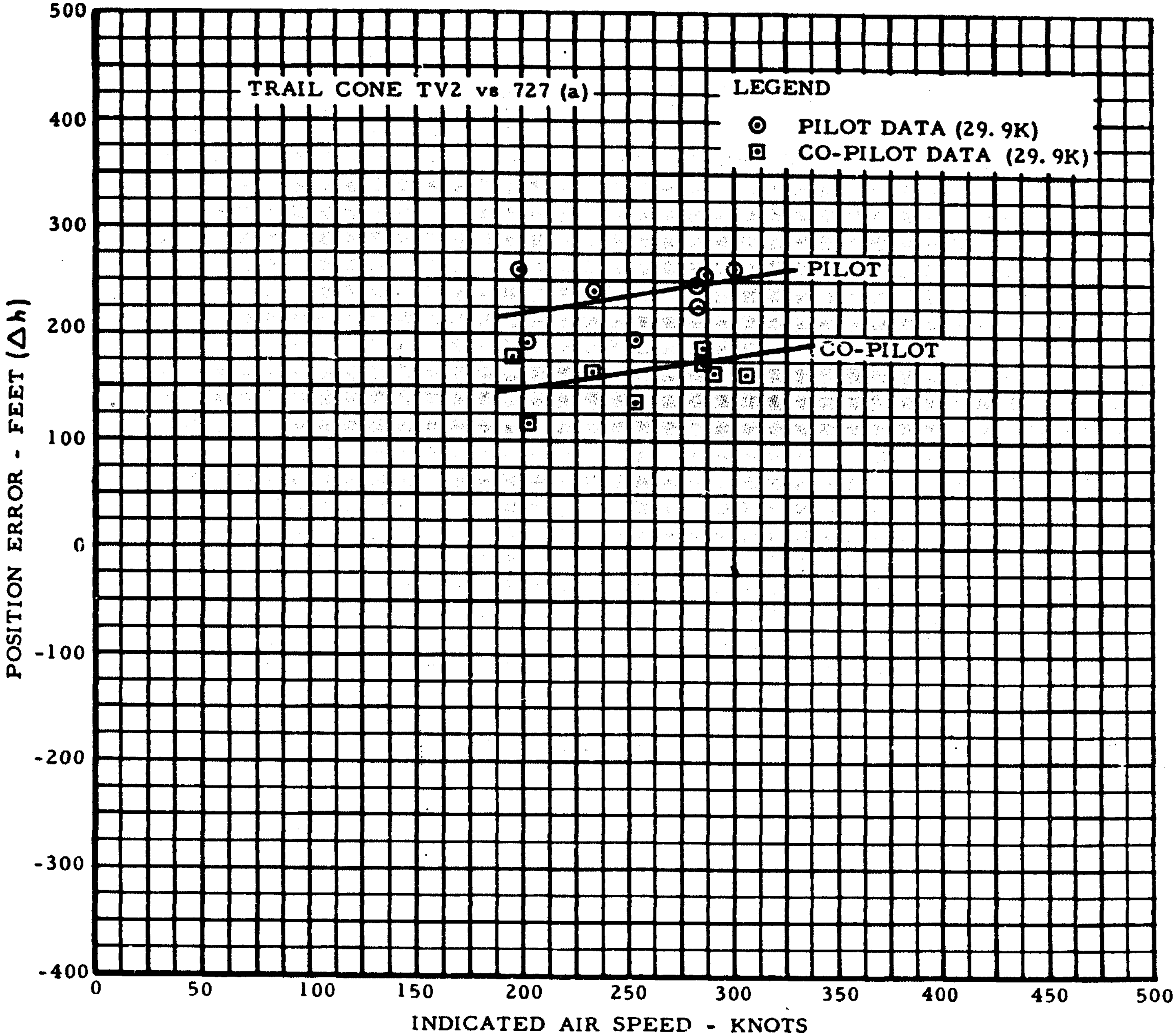

FIG. 4 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 727 AIRCRAFT (a)

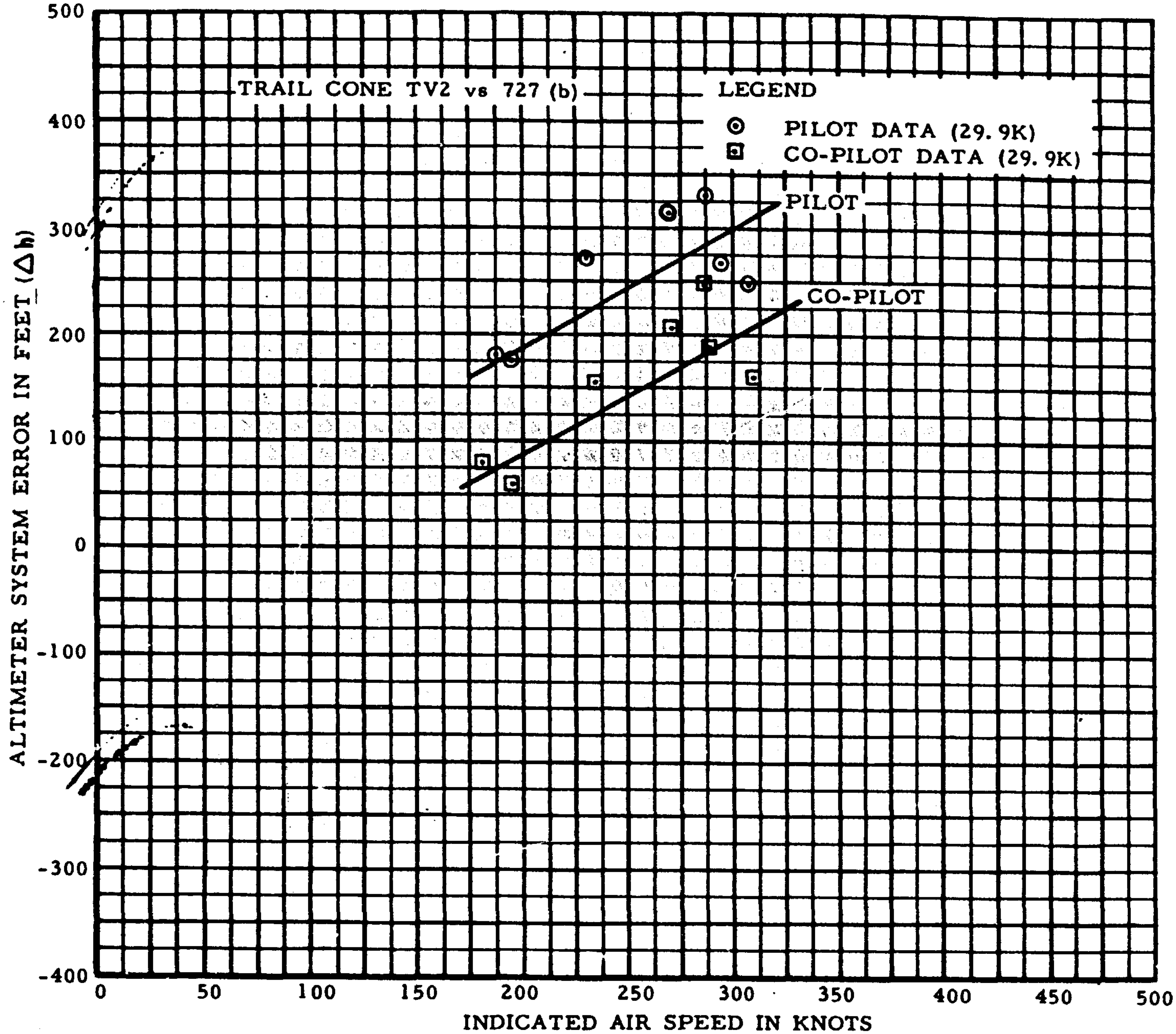

FIG. 5 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 727 AIRCRAFT (b)

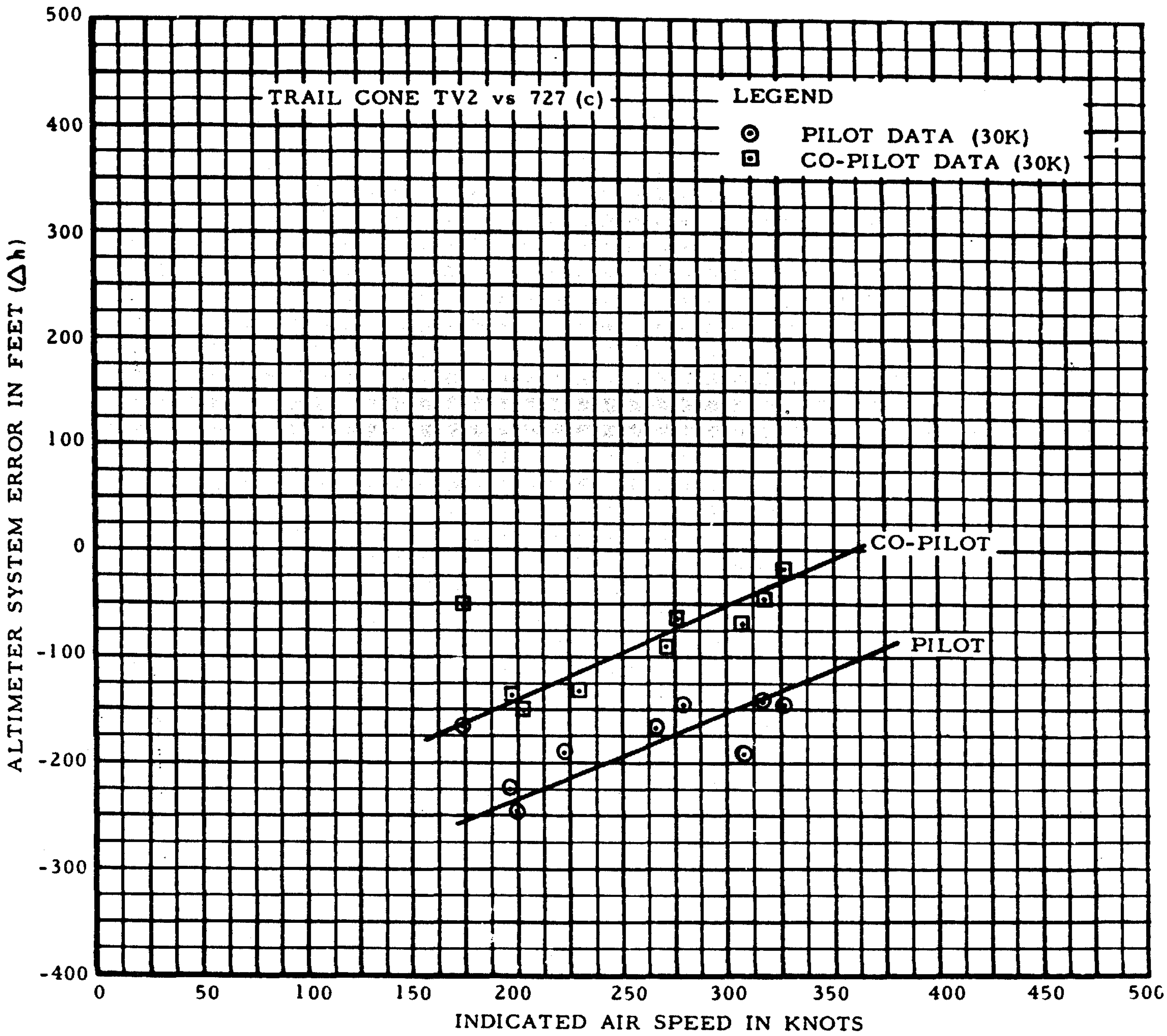

FIG. 6 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 727 AIRCRAFT (c)

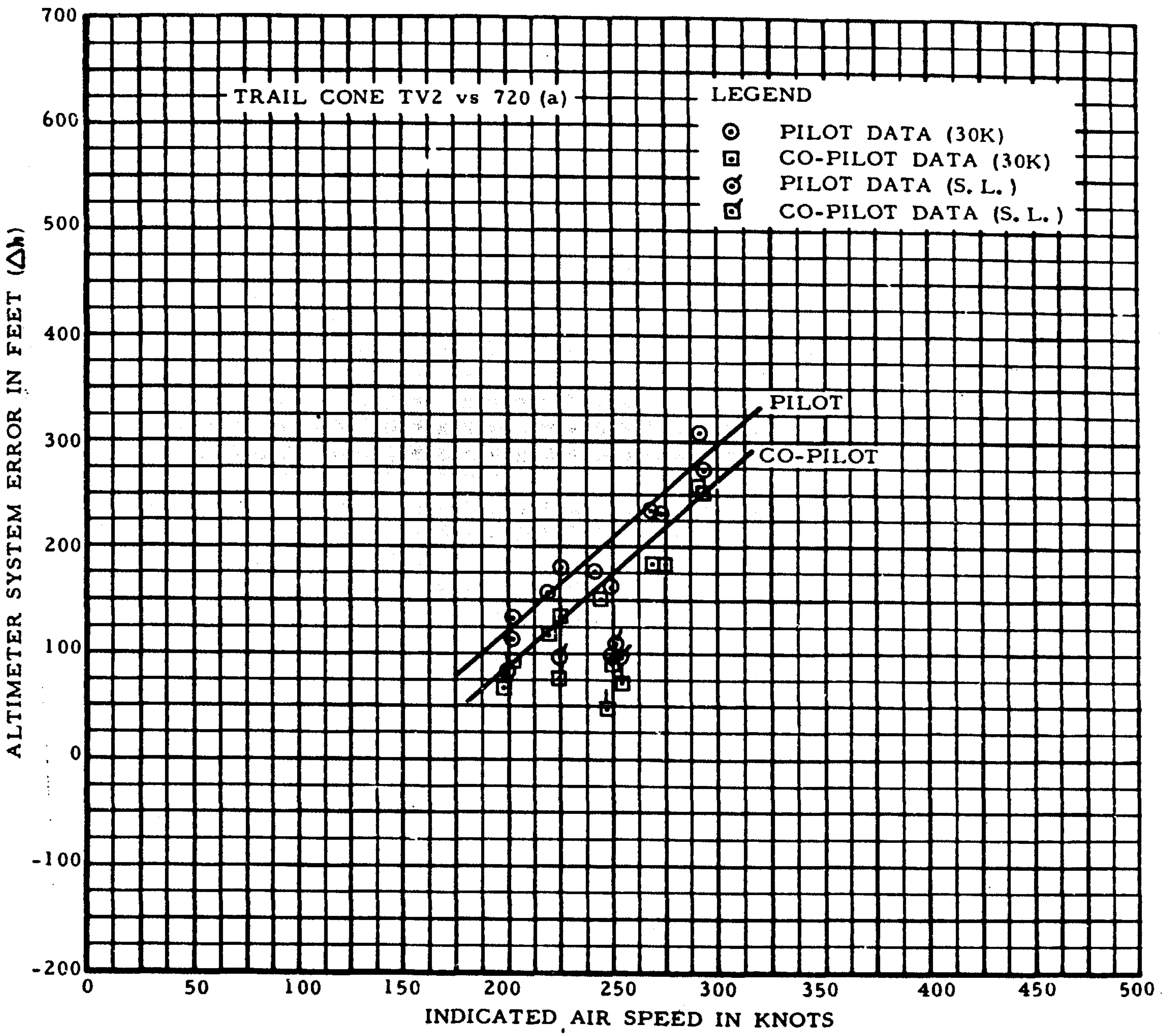

FIG. 7 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 720 AIRCRAFT (a)

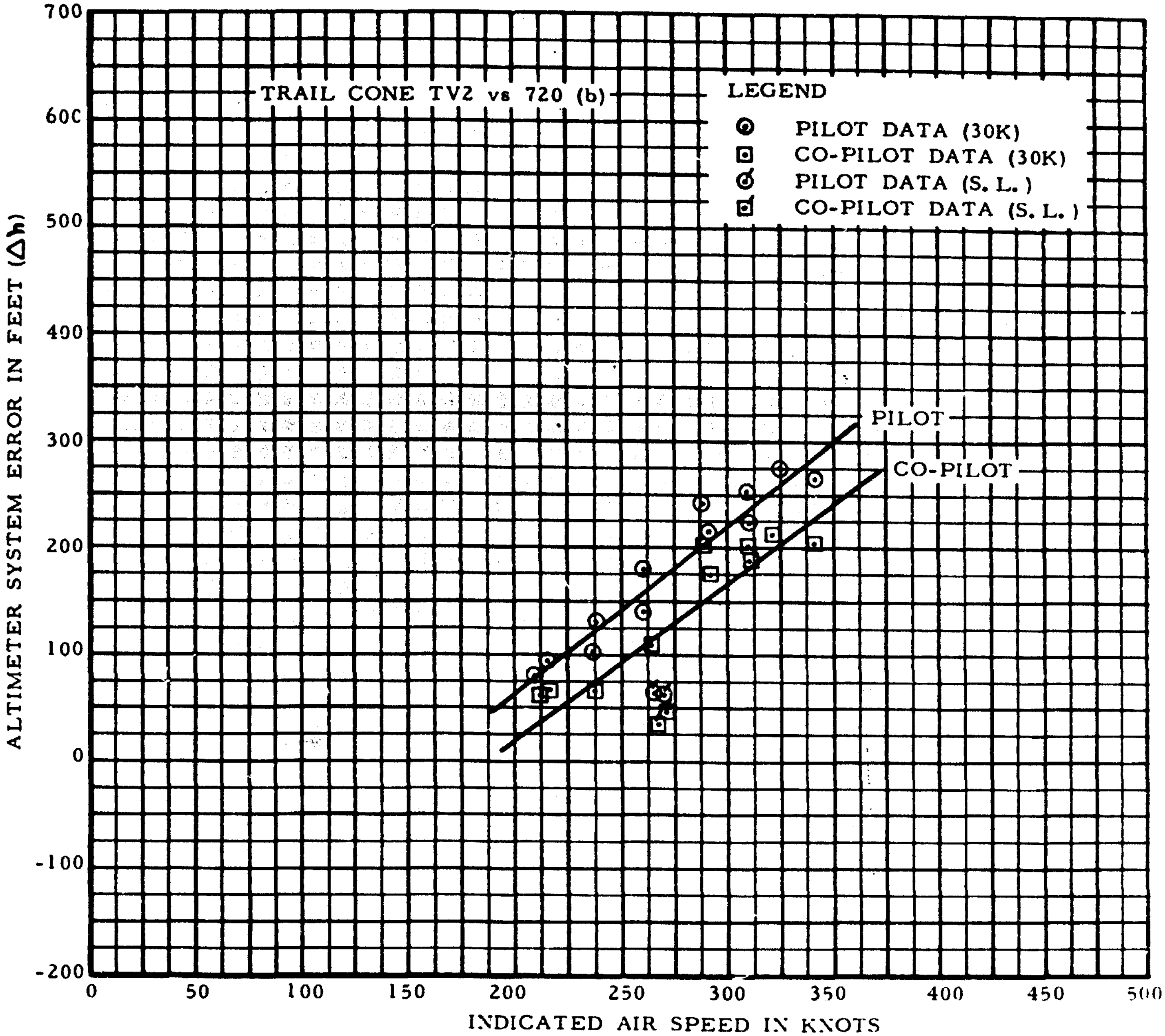

FIG. 8 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 720 AIRCRAFT (b)

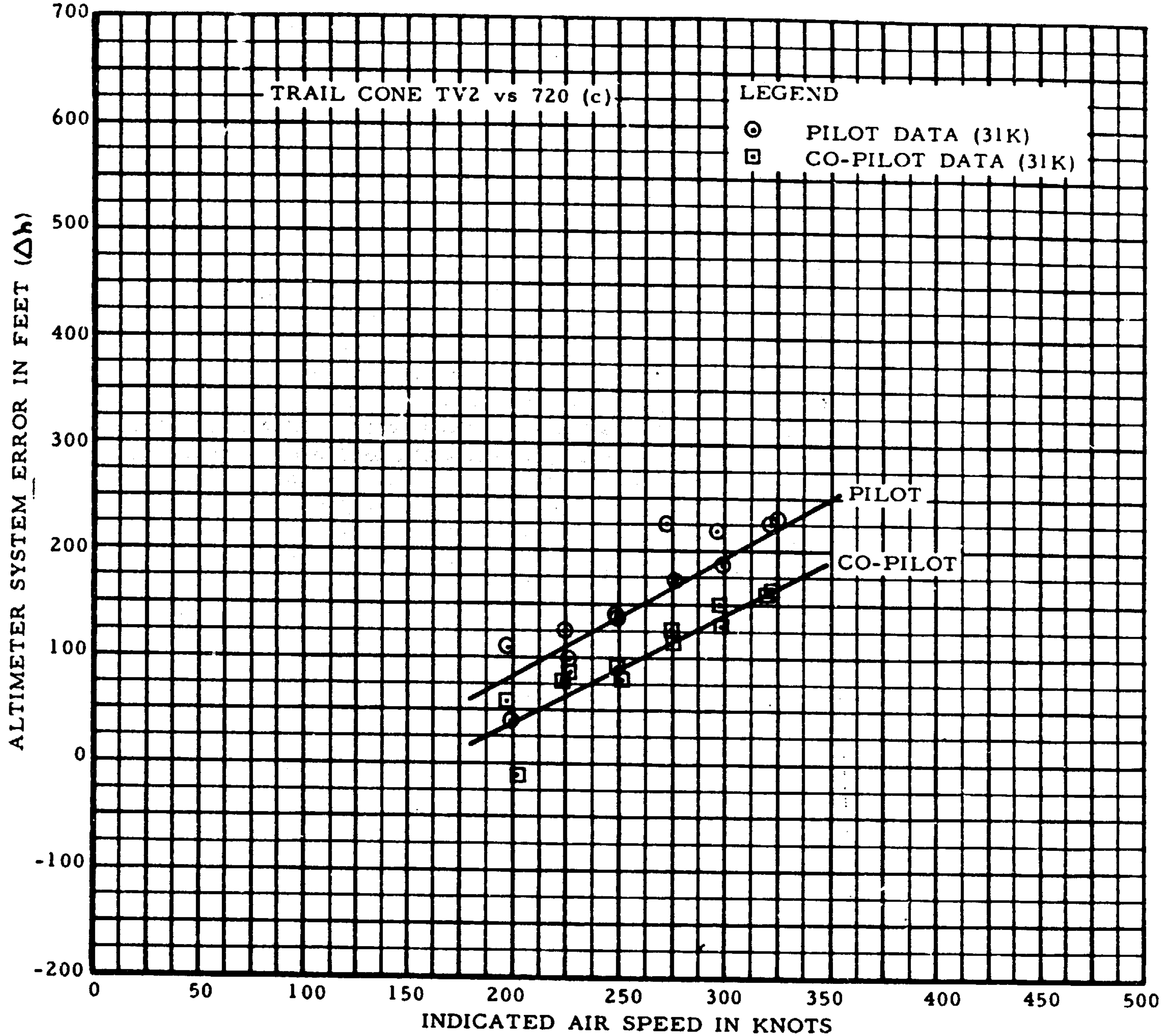

FIG. 9 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 720 AIRCRAFT (c)

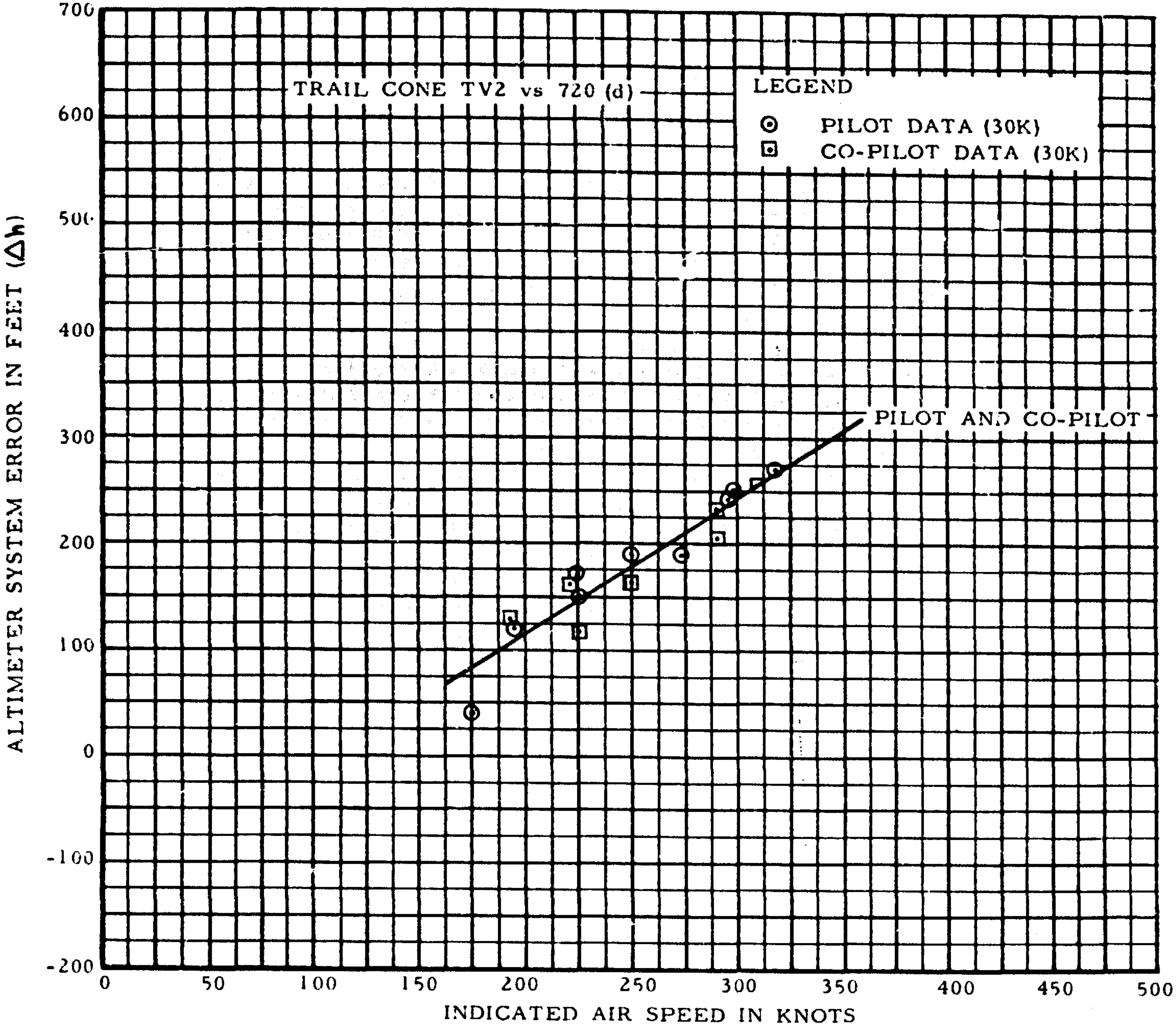

FIG. 10 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 720 AIRCRAFT (d)

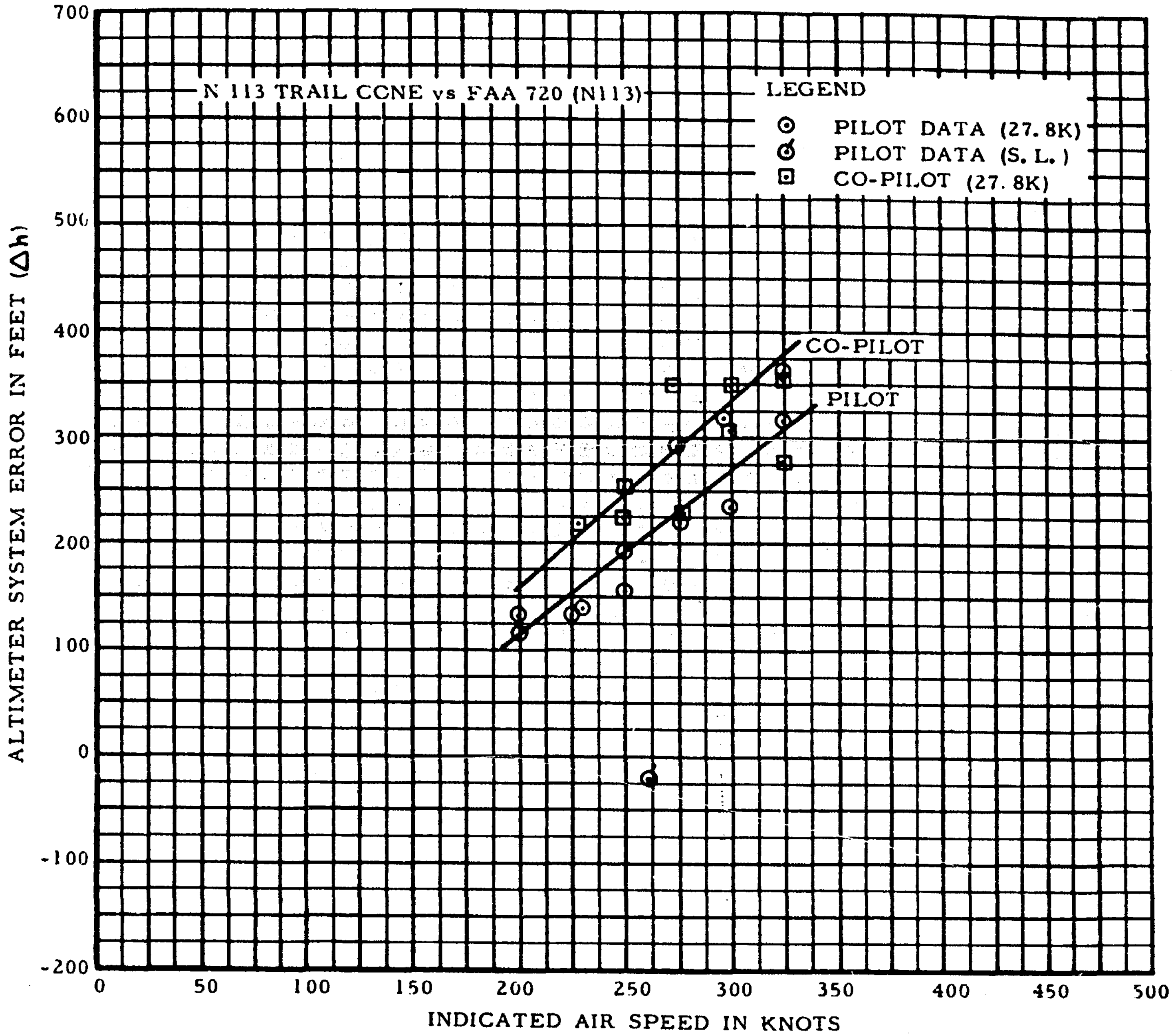

FIG. 11 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 720 AIRCRAFT FAA (N113)

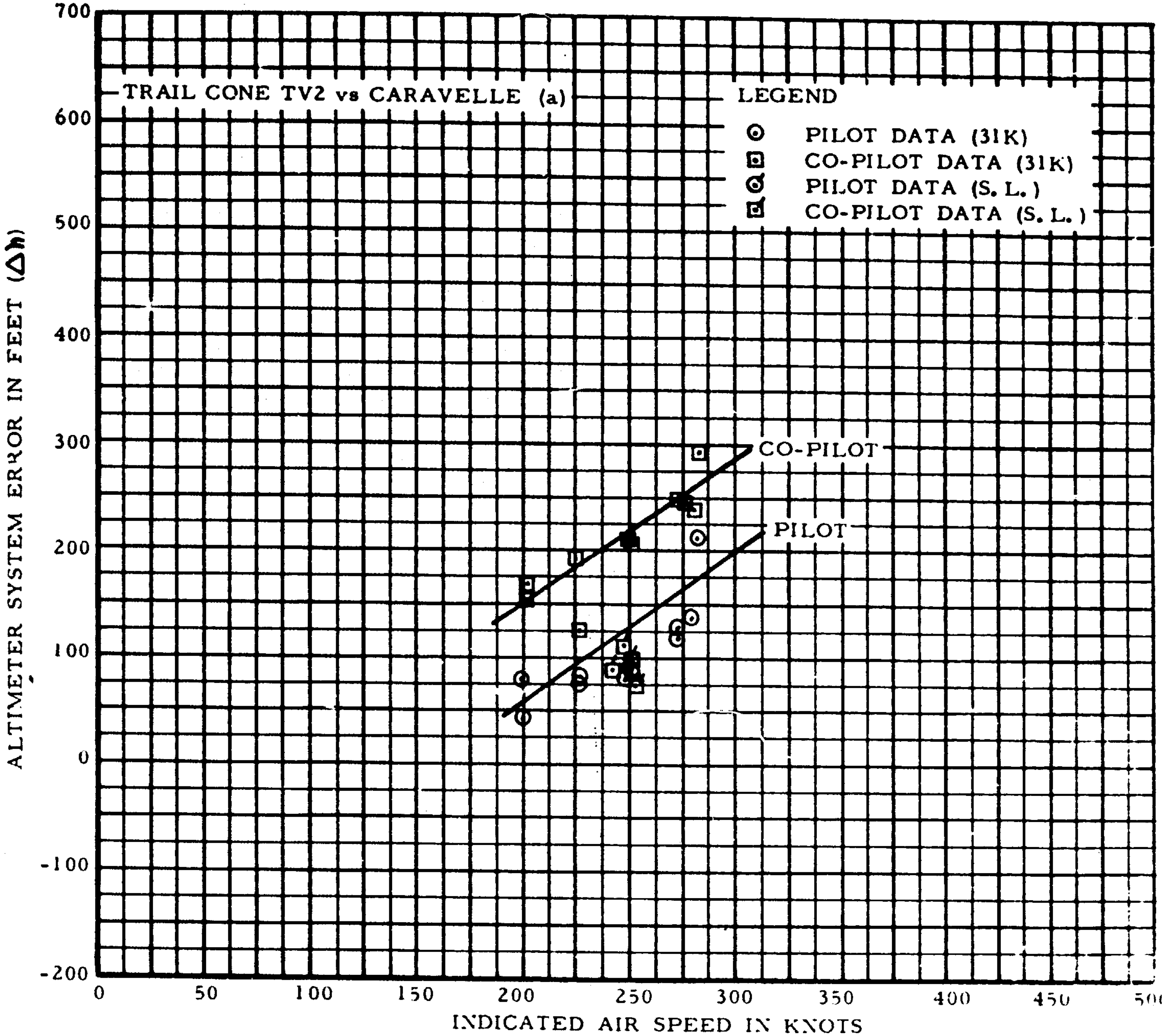

FIG. 12 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - CARAVELLE AIRCRAFT (a)

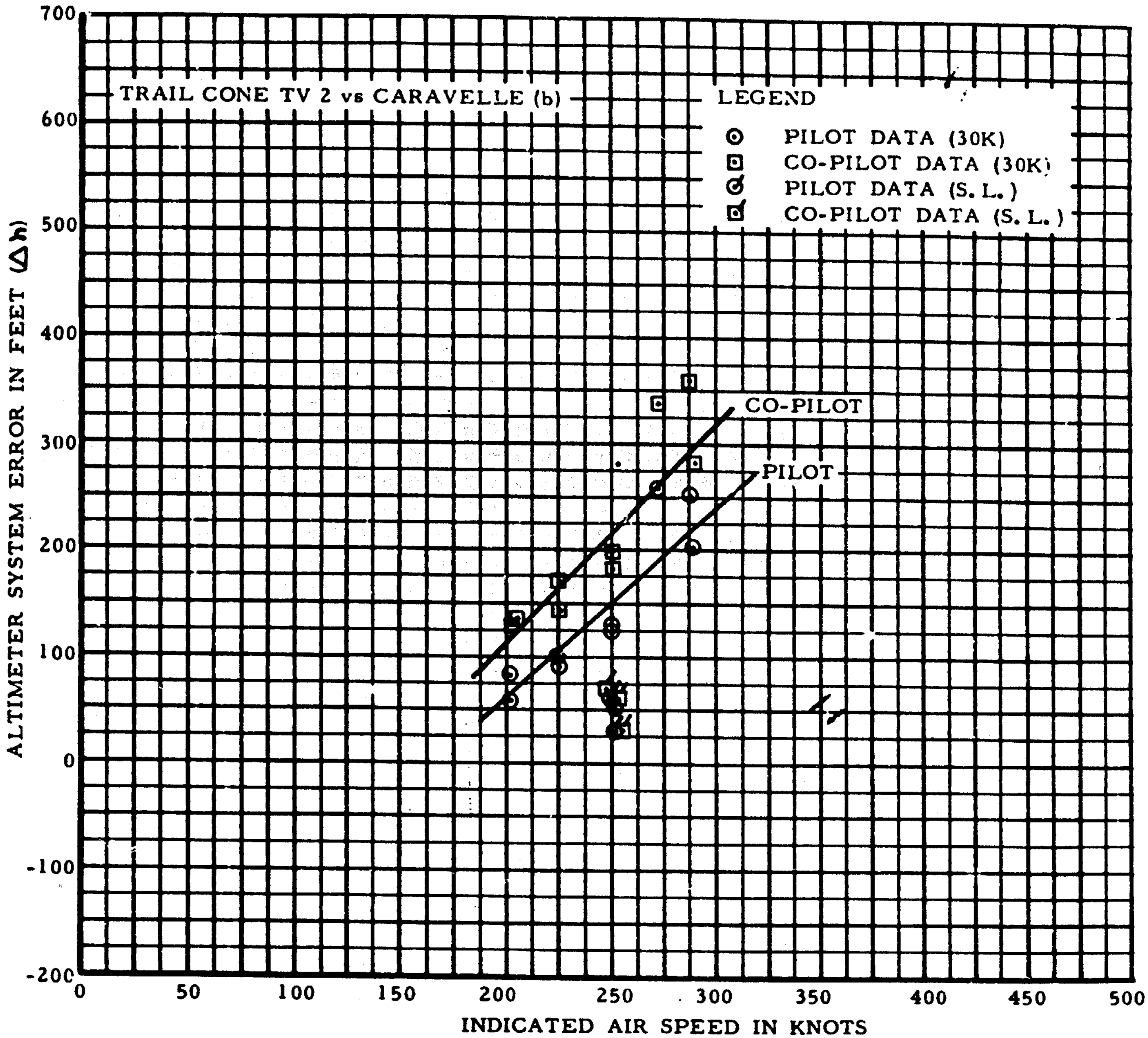

FIG. 13 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - CARAVELLE AIRCRAFT (b)

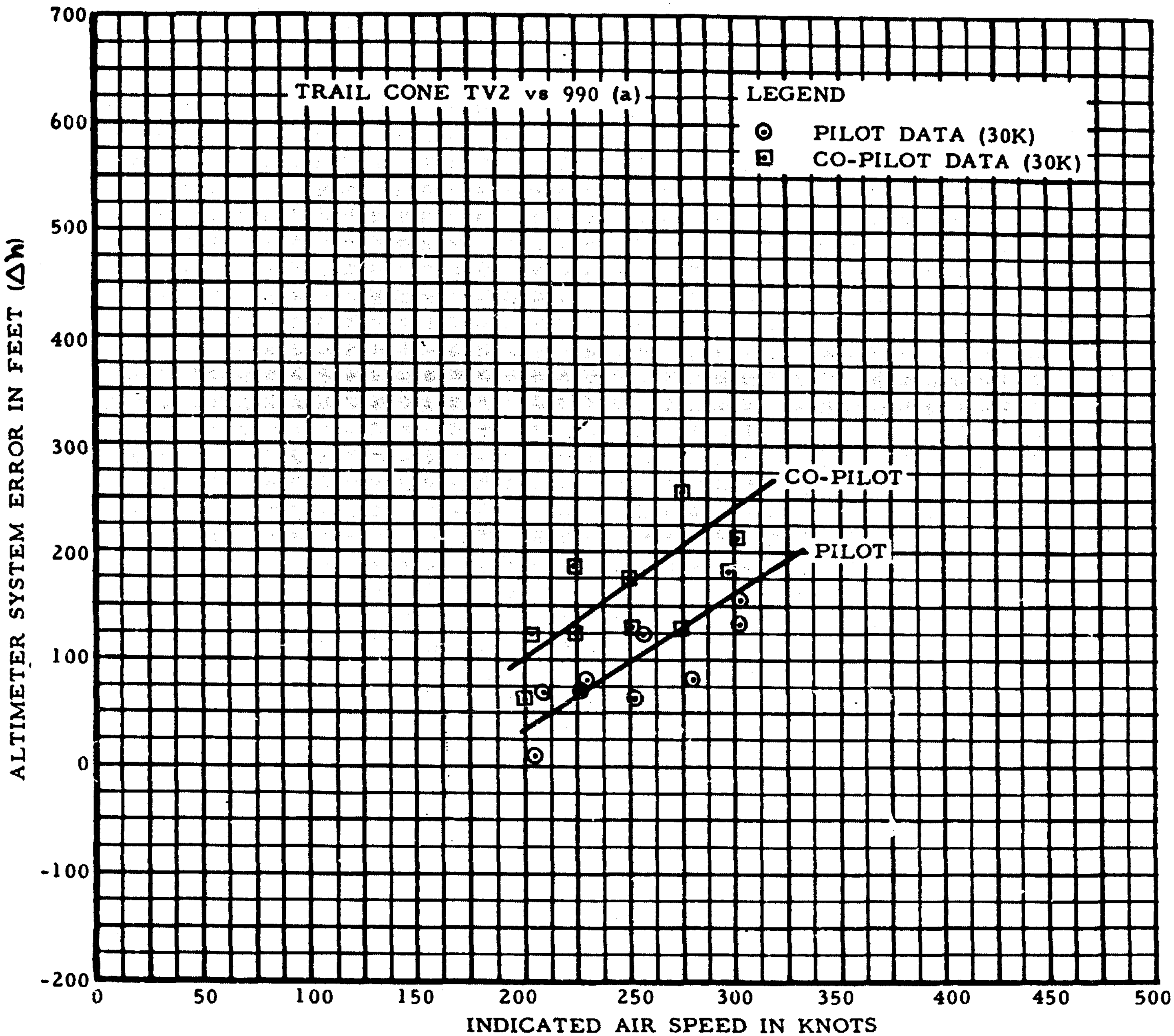

FIG. 14 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 990 AIRCRAFT (a)

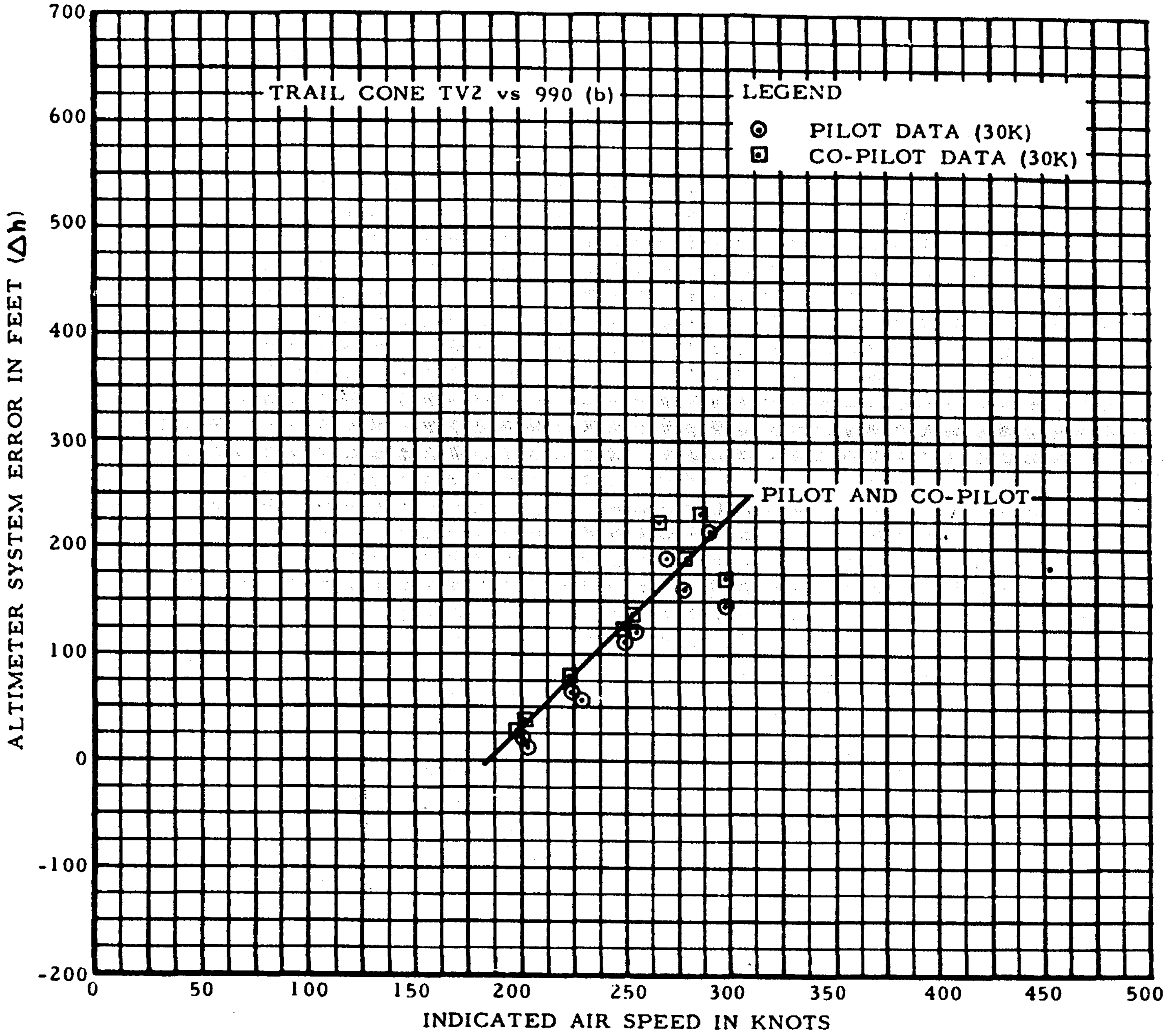

FIG. 15 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 990 AIRCRAFT (b)

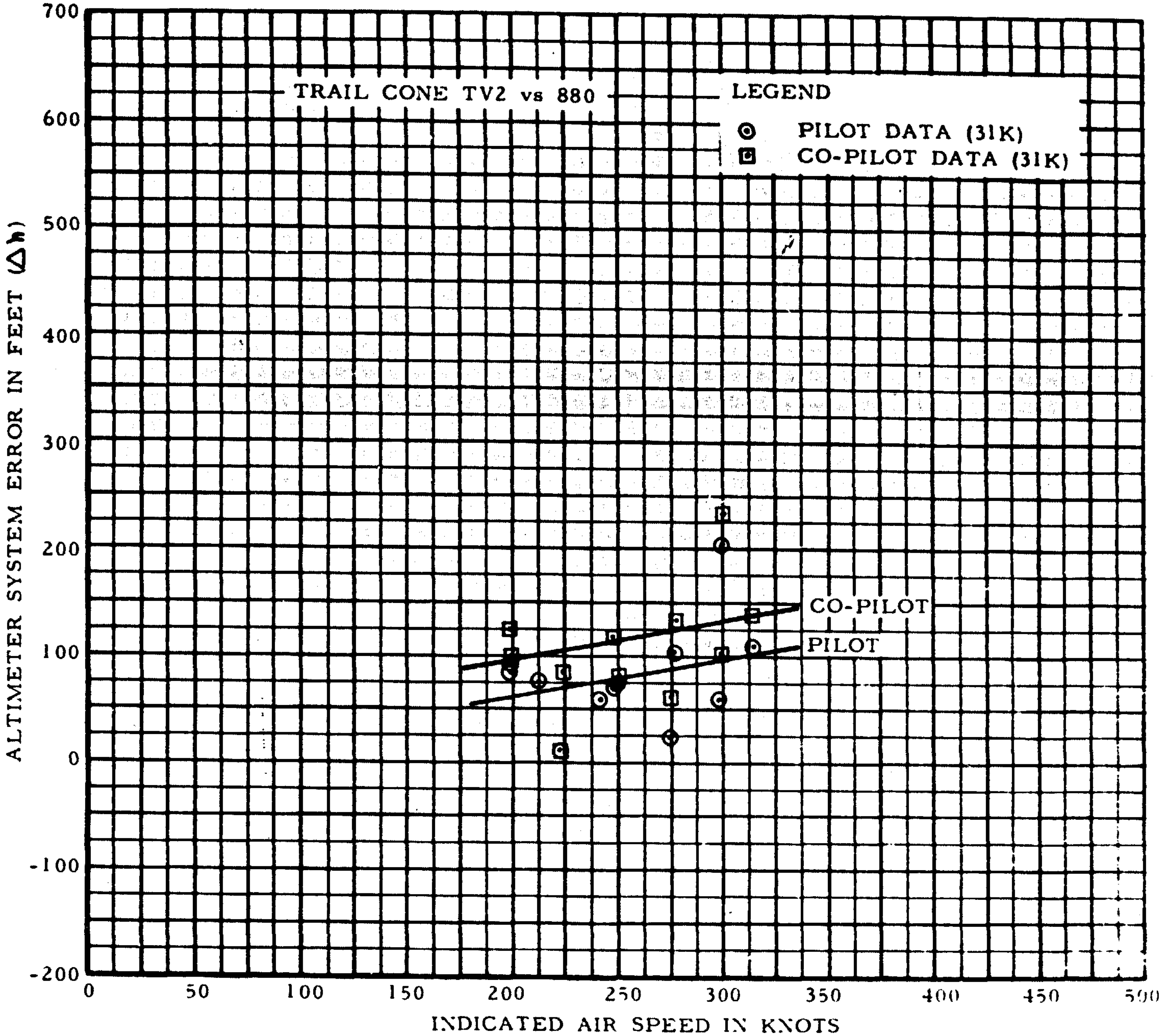

FIG. 16 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 880 AIRCRAFT

ERROR VERSUS INDICATED AIRSPEED - 727 AIRCRAFT

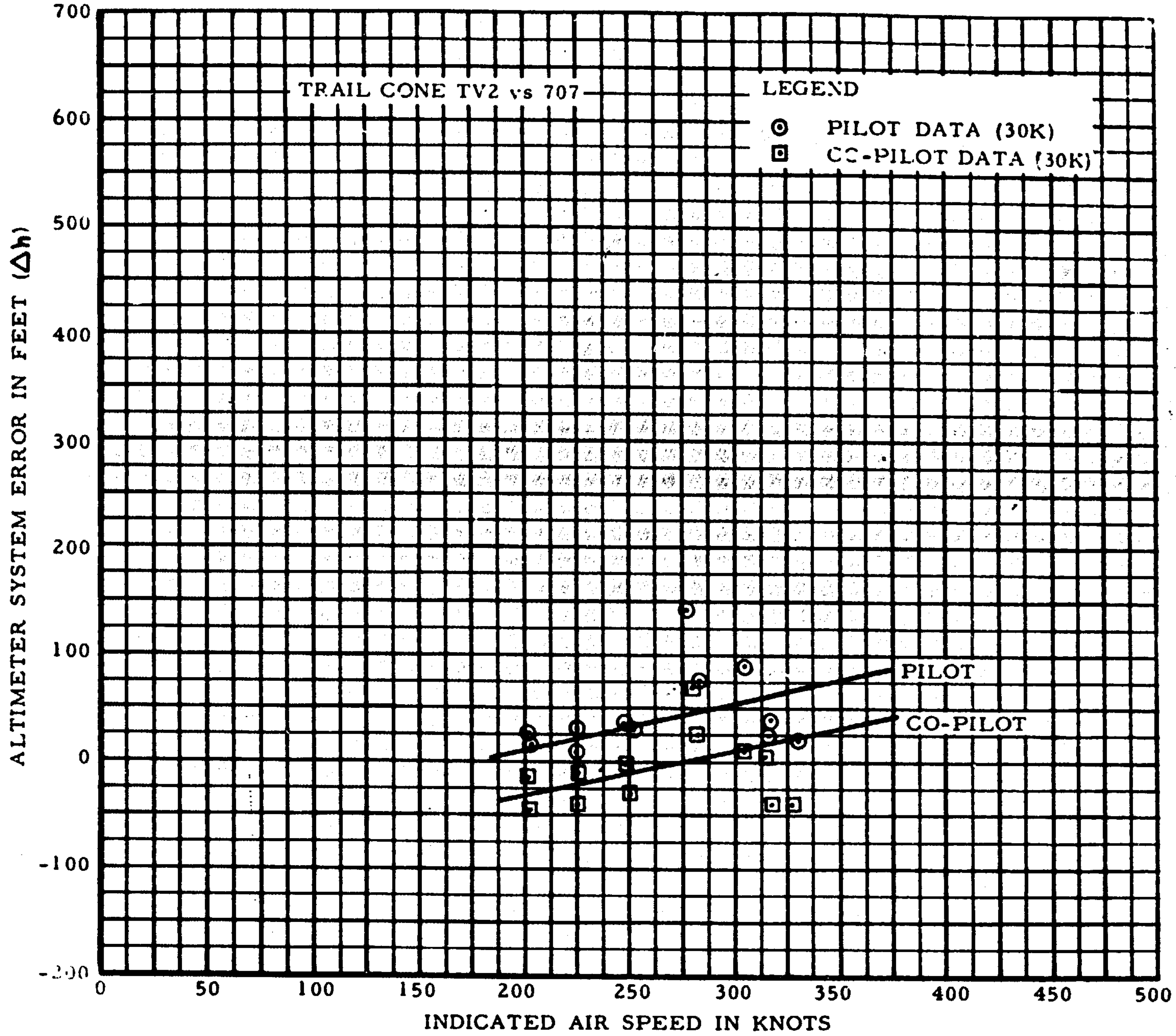

FIG. 17 APPARENT POSITION ERROR VERSUS INDICATED AIRSPEED - 707 AIRCRAFT

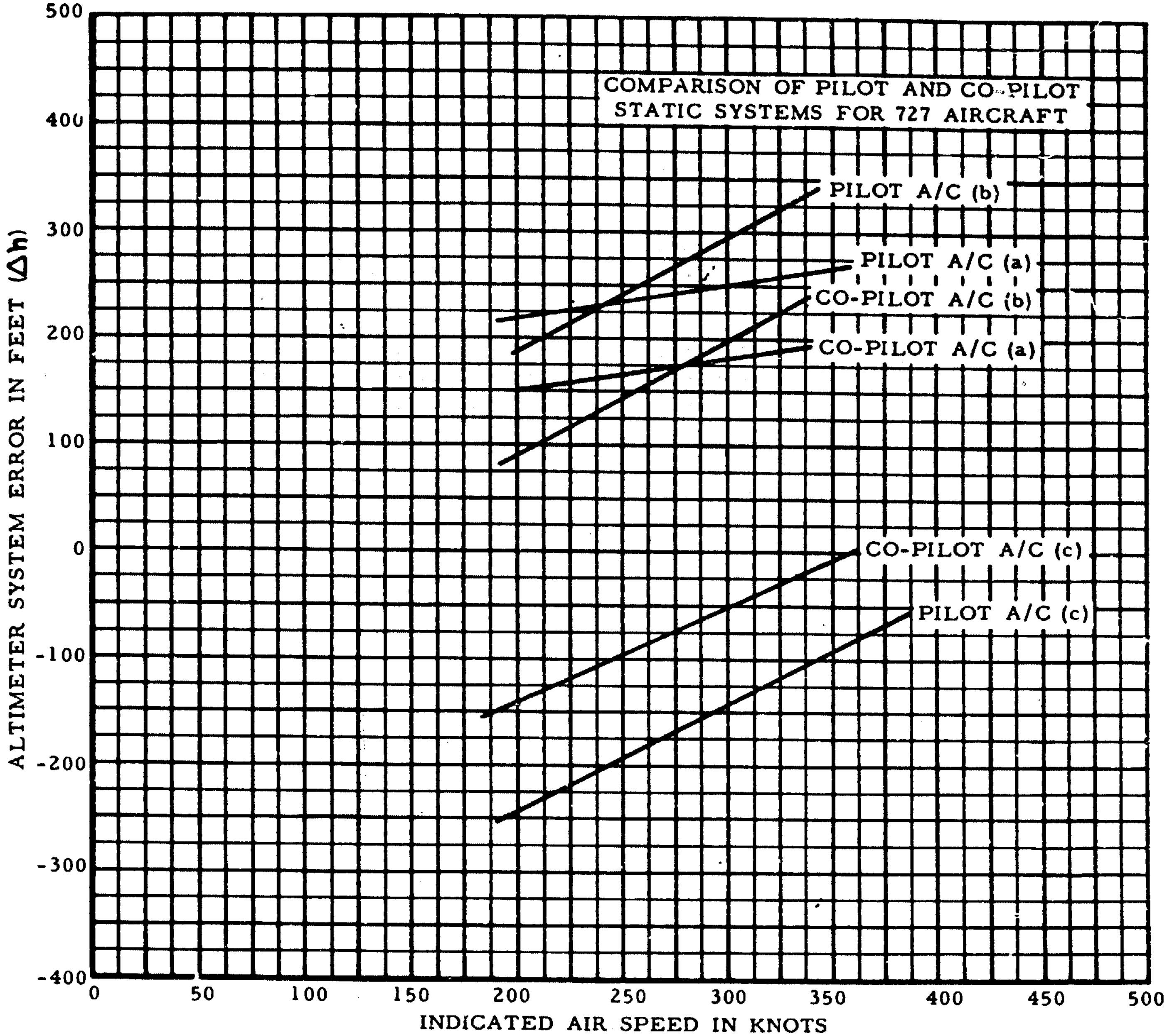

FIG. 18 COMPARISON OF STATISTICALLY-DERIVED POSITION ERROR VERSUS INDICATED AIRSPEED - 727 AIRCRAFT

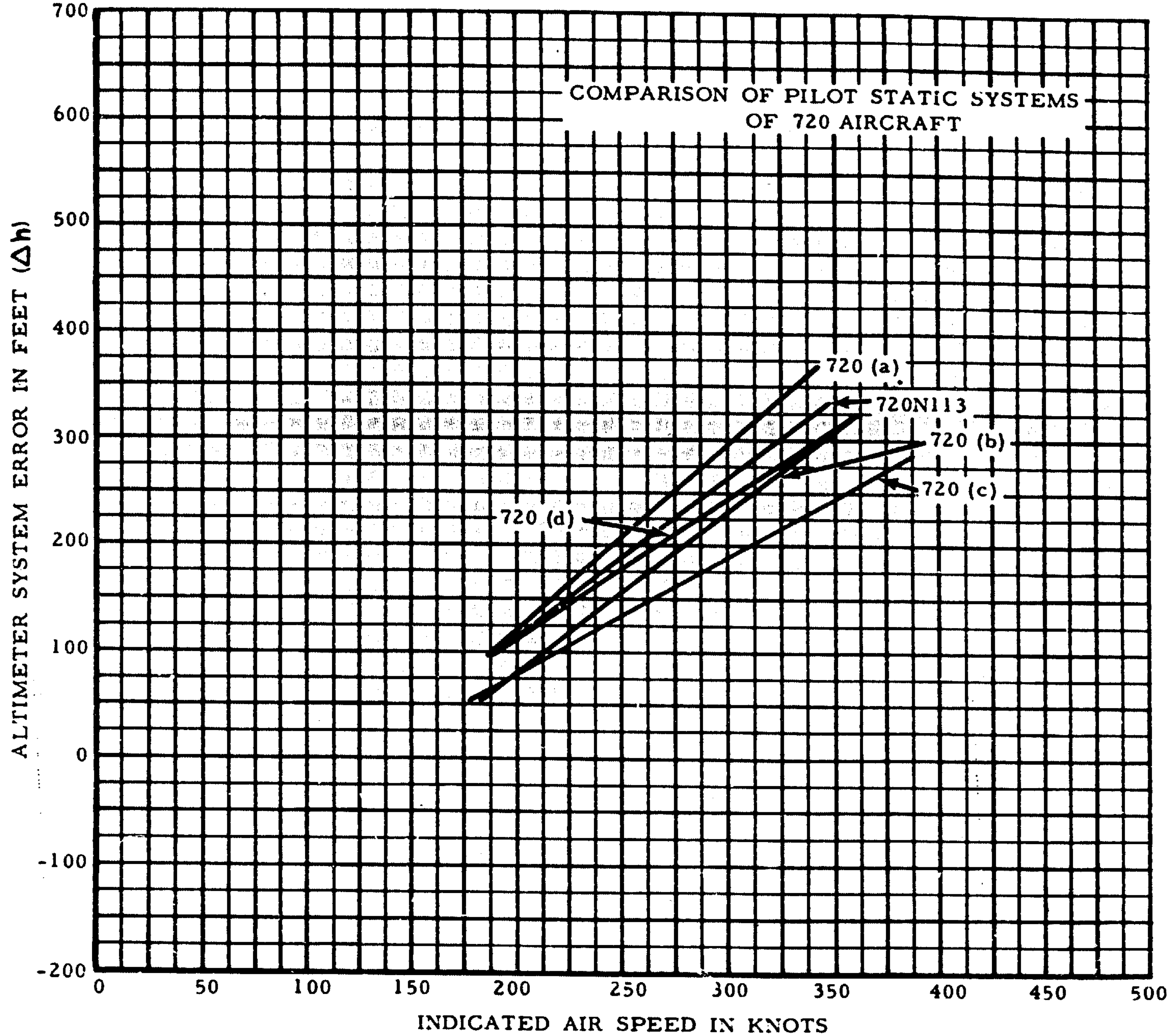

FIG. 19 COMPARISON OF STATISTICALLY-DERIVED POSITION ERROR VERSUS INDICATED AIRSPEED - 720 AIRCRAFT PILOT'S SYSTEM

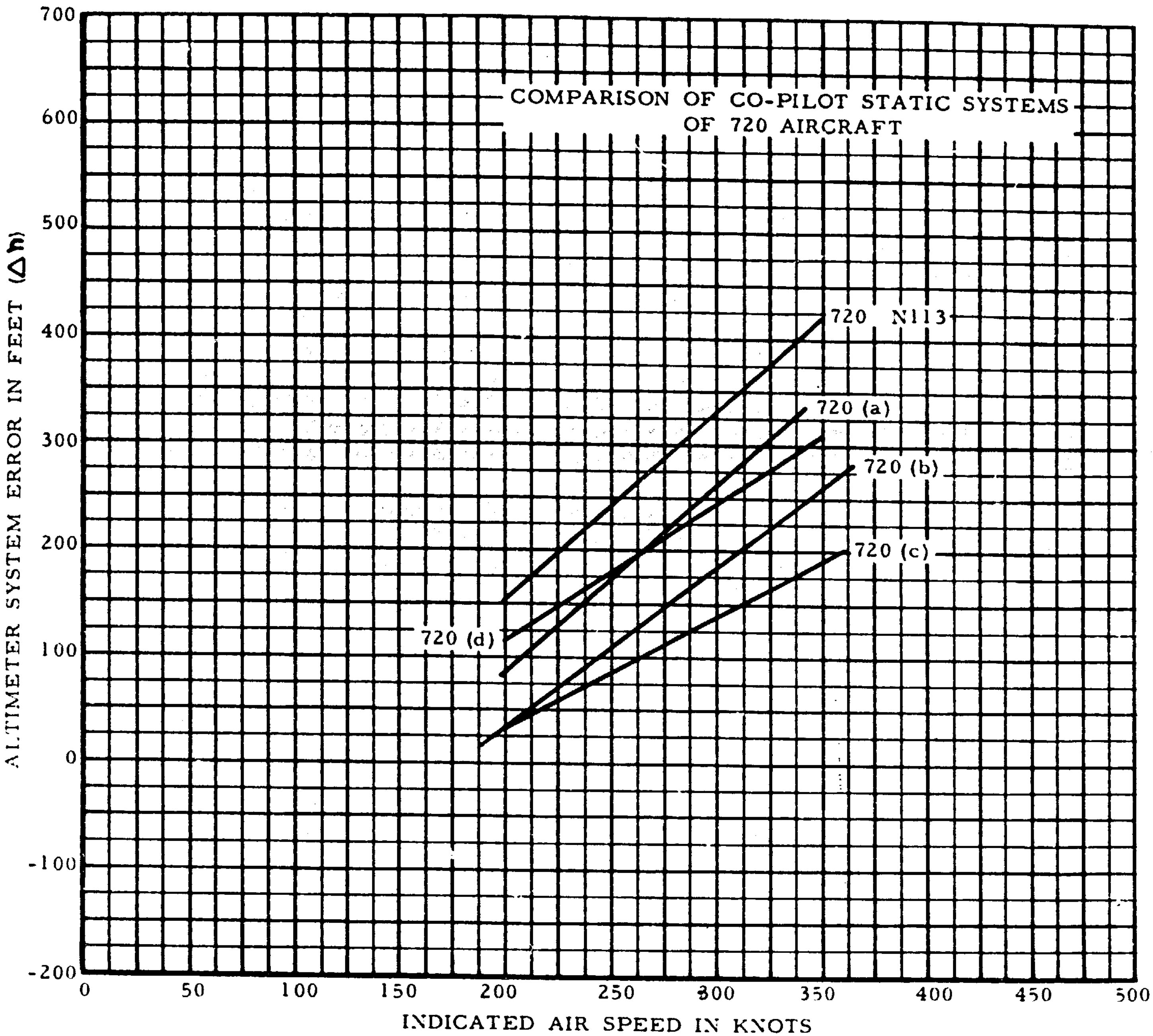

FIG. 20 COMPARISON OF STATISTICALLY-DERIVED POSITION ERROR VERSUS INDICATED AIRSPEED - 720 AIRCRAFT COPILOT'S SYSTEM

VERSUS INDICATED AIRSPEED - 990 AIRCRAFT

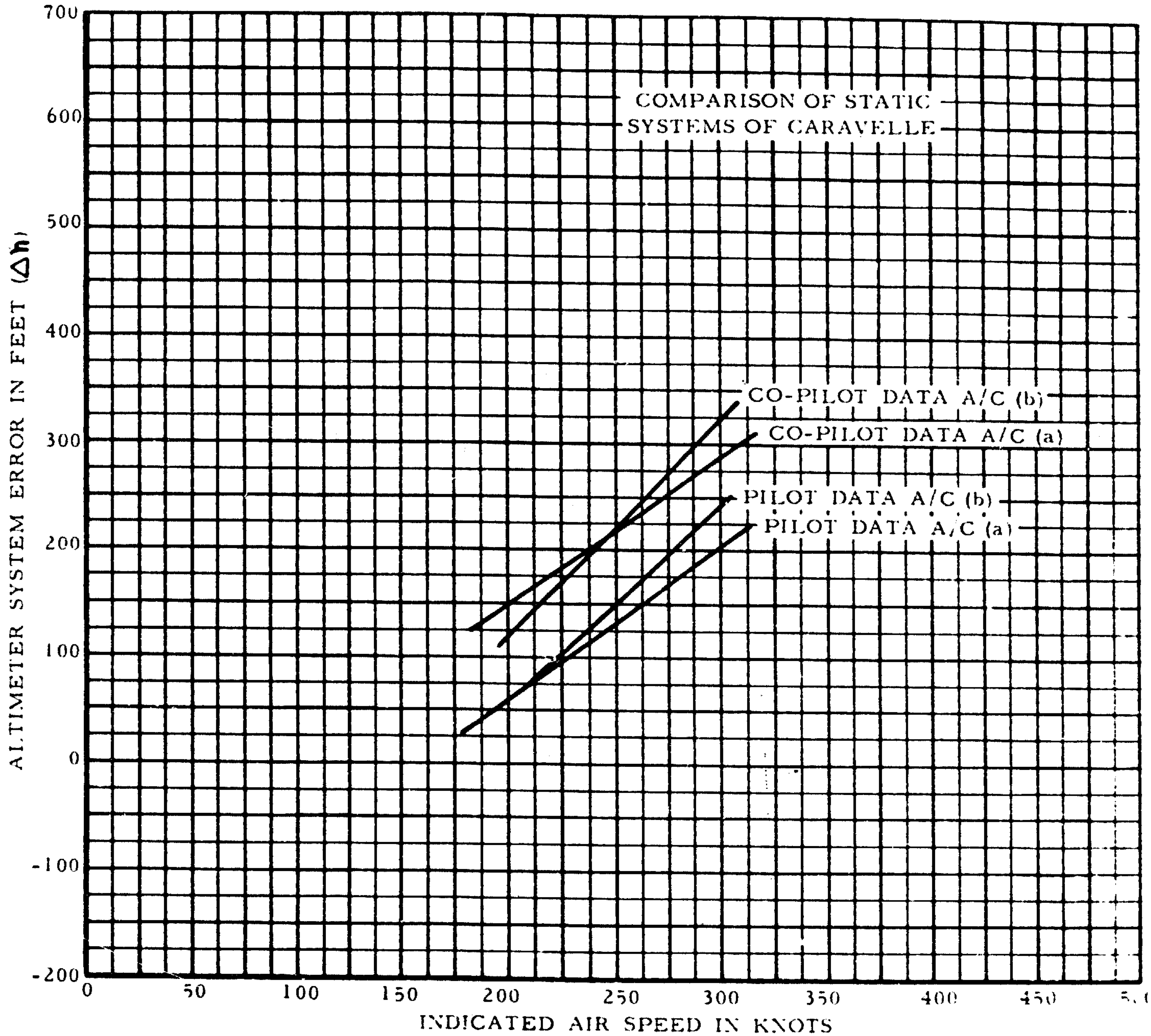

FIG. 21 COMPARISON OF STATISTICALLY-DERIVED POSITION ERROR VERSUS INDICATED AIRSPEED - CARAVELLE AIRCRAFT

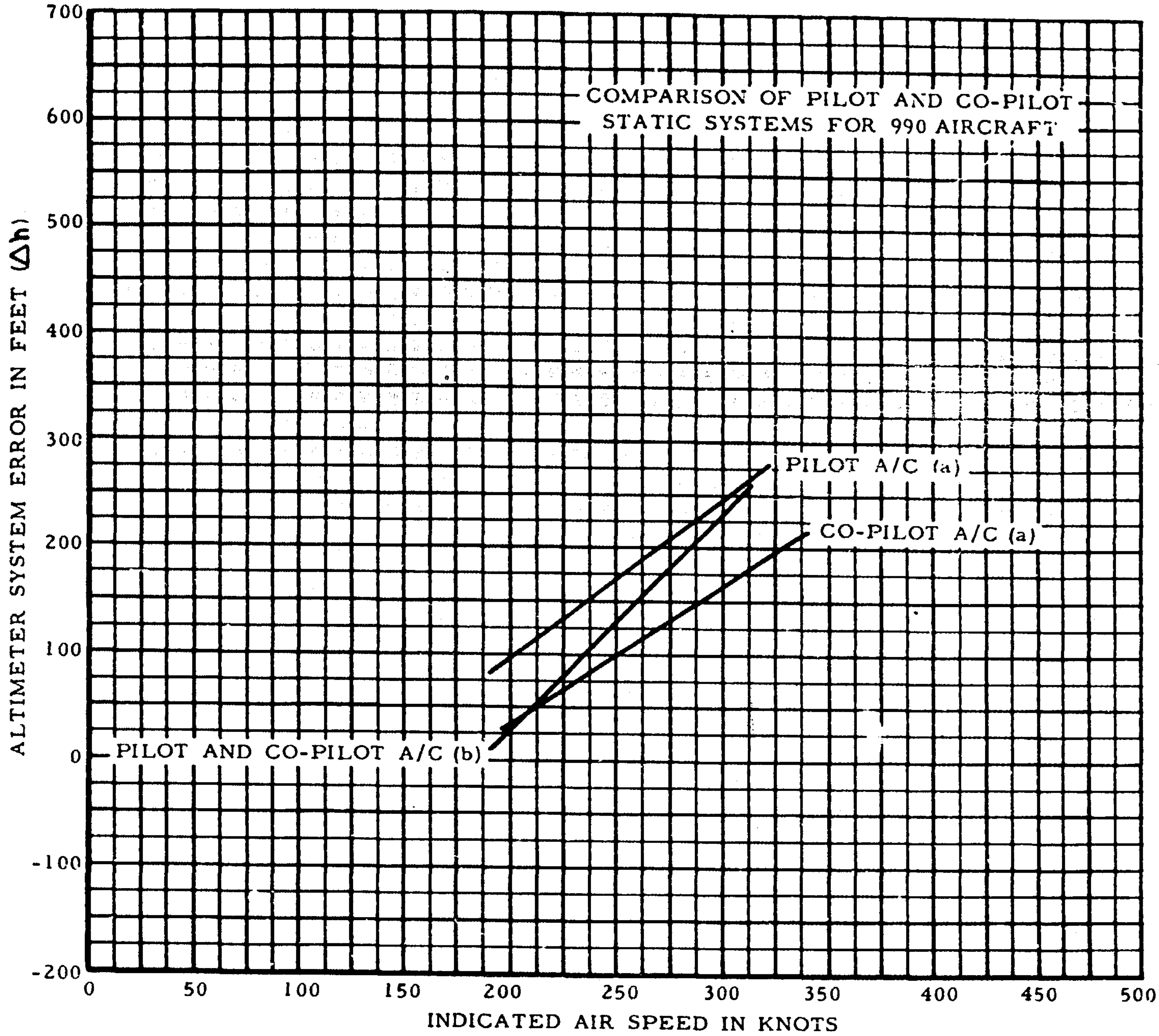

FIG. 22 COMPARISON OF STATISTICALLY-DERIVED POSITION ERROR VERSUS INDICATED AIRSPEED - 990 AIRCRAFT

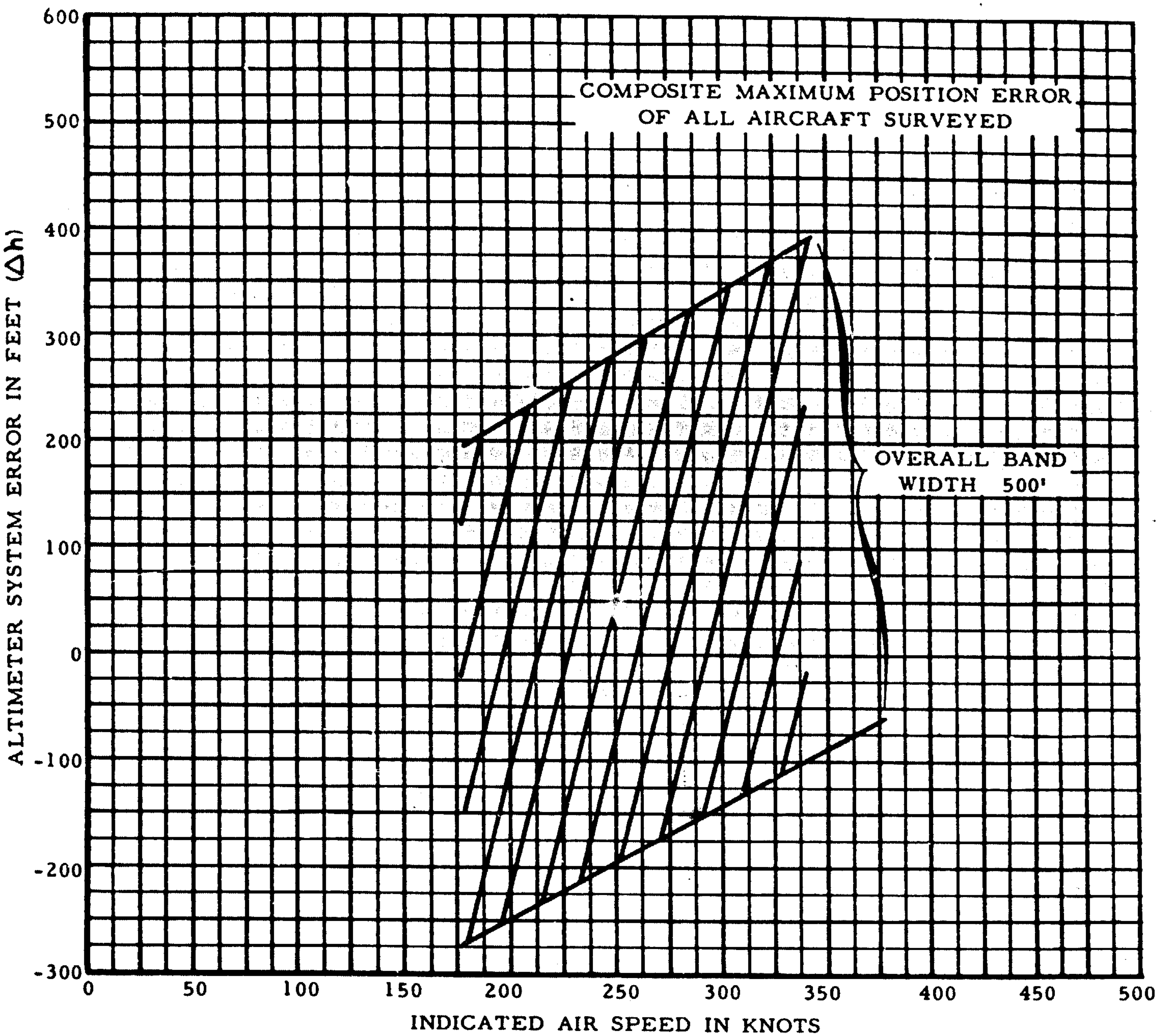

FIG. 23 COMPOSITE OF MAXIMUM STATISTICALLY-DERIVED POSITION ERROR VERSUS INDICATED AIRSPEED - ALL AIRCRAFT

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<u>Descriptors</u>

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Civil Aviation
Airspeed
Airworthiness
Aviation Safety

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